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Chapter

Introductory Chapter: Functional Textiles

Bipin Kumar and Viraj Somkuwar

1. Introduction

Recent developments in high-performance fibers, fabrics, and manufacturing technologies become the main driving force behind the emergence of functional textiles. The majority of functional textiles were originally used in defense applications, but due to their popularity, they are now available to the general population. The field of functional clothing is vast and varied, with each function having its own set of specifications, material needs, and corresponding technologies and methods. Hence, the designing and from the prospect of manufacturing, the functional clothing becomes a challenge due to limited set of standards and varying requirements according to the needs. Functional textiles have a wide range of applications, including saving lives, adapting to hostile environments, and improving performance and quality of life [1, 2].

The recent COVID-19 epidemic had a significant impact on the world, posing difficulties to the health care infrastructure, society, culture, and economic system. The outbreak has failed all the advance medical treatments, but the crucial role was played by the non-pharmaceutical measures in reducing the transmission of viruses. The functional and smart textile has played a crucial role in designing the personal protective equipment (PPE) and telemedicine for strengthening the healthcare system. The breakthrough research in the field of nanomaterial, surface treatments, and finishing technology has given an edge to the functional textiles to successfully prevent this spread of viruses and disease. The personal protective equipment such as masks, surgical gowns, and gloves are the examples of textile functional clothing used for COVID19 protection. The fabrics were treated with antiviral and antimicrobial treatment to enhance its protection efficiency [3–5]. Another major factors that help the people during the lockdown situation are the telemedicine technology, which again mainly depends upon the smart and wearable textile which contains some electronic sensing functionality. The functional clothing used for telemedicine contains, electronic-embedded sensor, or the textile material itself converted into the sensor, which monitor the human vital parameters, such as heart rate, breathing pattern, blood oxygen level [6].

The focus of this book is to review key materials, manufacturing technologies, and the application methodologies for the designing and development of functional and technical textiles. This chapter will provide an overview of the principles of different types of functional textiles and their applications in various industries.

1.1 Functional textile: definition

All the textile clothing is meant to perform several objectives in our daily life from esthetics to provide basic protection from the various external factors. "Functional clothing" can therefore be defined as "a generic term that includes all

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such types of clothing or assemblies that are specifically engineered to deliver a pre-defined performance or functionality to the user, over and above its normal functions" [7]. This type of clothing can be produced by using high-performance fiber, novelty finishes, or intrinsic modification of conventional material. The clothing is expected to perform some specific functions, which can be protecting the person from a hazardous working environment, facilitating the movement during sporting activity, assisting a physically challenged individual or enhancing the endurance of a sports person. Functional clothing can be used for protection against the life-threatening viruses and diseases in medical treatment. It can also have the electronic functionality embedded inside the clothing, which can be used for transmitting the signals wirelessly and monitor the human vital to provide telemedicine facilities [1].

1.2 Classification of functional textiles

The standard technical textile is categorized according to the application, such as Sportech (sports textile), Protech (protective textile), and MedTech (medical textile). Designing a product for a specific end user opens up a new classification system that includes current technology. The classification for the functional textile can be made according to the functionality and requirements. As the material, manufacturing technology may be the same or varied for the specific application. For example, material selection is based on the user's physiological and psychological needs, whereas technology is chosen based on the required functionality, ergonomics, comfort, and fit (**Table 1**).

1.2.1 Protective clothing

It is one of the largest areas of functional clothing. The designing of the fabric varies for every function and required special attention. Environmental factors such as heat, cold, snow, and wind demand different types of fiber, fabric construction, and treatment. The challenge in designing the protective clothing is to offer maximum protection without affecting the metabolic heat transmission [8]. A fire protective clothing assembly schematic is shown in **Figure 1**, depicting the fabric layer arrangement to protect the skin from different hazards and simultaneously maintaining the body's thermal balance [9, 10]. Some primary requirements are

Class	Description
Protective clothing	Environmental protection—extreme heat or cold, rain, snow, dust, UV rays Biological, chemical, and radiation—hazardous chemicals, toxic gases, germs, radioactive substances Injury protection—cut, ballistic, impact protection
Medical functional clothing	Surgical protection—viruses, germs, bacterial protection Therapeutic—pressure management in lymphatic and venous disorder, scar management
Wearable clothing	Sensing—biological and physiological monitoring, telemedicine Communication—wireless monitoring, remotely tracking
Sports clothing	Training—performance enhancement, fatigue management, body shaping Activewear—moisture, sweat management, heat stress management
Special needs clothing	Clothing for the elderly, pregnant women, infants, and disabled

Table 1.
Classification of functional textile clothing.

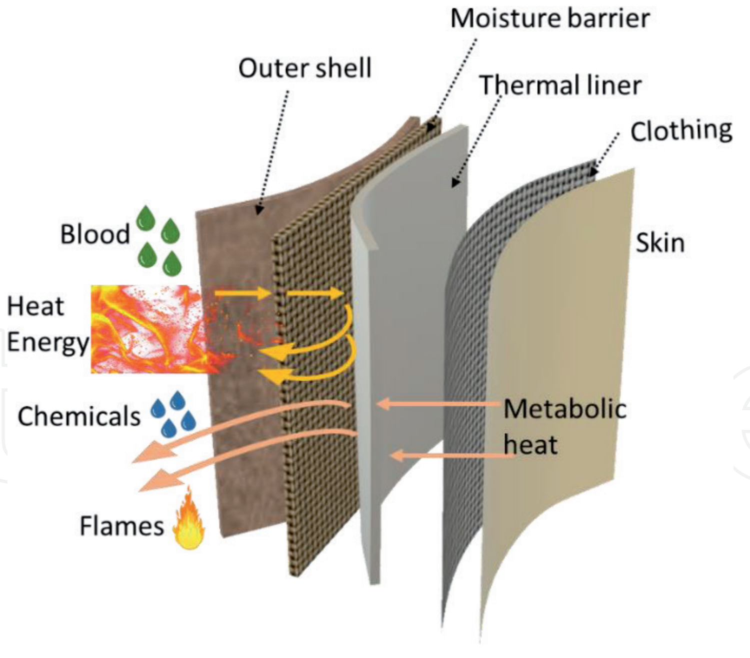

Figure 1.
Fire-protective functional clothing assembly.

lighter weight and volume, ergonomic design, and better moisture management. The biological, chemical, and radiation protection demands a barrier between the source of radiation and the human skin; hence, the clothing should contain a reflective material or a coating to prevent the penetration of these substances through the clothing [11, 12].

1.2.2 Medical functional clothing

Textiles have been utilized for medical treatment from a long time for surgery, wound protection, etc. The major function of this clothing is to protect from the bacteria, viruses, and body fluid infection. The clothing uses intrinsic antimicrobial textile material or substances coated onto the fabric. The fabric used for therapeutic treatments uses elastic garment to impart a compression on the infected area. The pressure exerted by the compression garments helps in the movement of the blood and lymphatic fluid from the affected area to reduce the venous disease. The pressure garments use elastic yarn and fabric construction, such as knitting to develop compression garments [13–15]. The functional clothing used for COVID19 protection uses a nonwoven fabric as a filter medium in the mask and PPE kit. Nonwoven fabric's porosity can be modified to obtain appropriate virus protection, and they can be coated with antiviral and antibacterial compounds to improve their protective performance [3–5].

1.2.3 Wearable clothing

Textile-based monitoring and treatment devices are becoming more preferable due to comfortability and portability, and use discretely and carefully among children and elderly people. Furthermore, the interactive textiles can be utilized for real-time monitoring and ultra-personalization, such as data measurement and storage for individual customers to have accurate and precise diagnoses [16–18]. There are several textiles-based TENGs applications reported in real-time monitoring, such as heart rate detection (ECG), neurobiological rehabilitation, gait recognition, pulse detection, motion sensors, respiration detection, and thermotherapy [17, 19–21]. E-textiles constitute two domains—textiles and electronics, which vary in type, material, and behavior from each other. Textiles are soft, flexible, porous, and susceptible to different conditions, while in general, electronics are rigid, precise, and guarded. It is always challenging to achieve material-specific properties for the wearable application while complying with the contrasting properties of electronics and textiles. Triboelectric nanogenerator (TENG) devices constitute one such platform for merging textile with electronics. The TENGs use the triboelectric effect and electrostatic induction to transform mechanical energy into electricity. The self-generation of an electrical signal without any power supply and the response to the health stimulus creates the TENG as a viable alternative for the wearable monitoring applications. The triboelectric effect is well known for almost a thousand years, through which material becomes electrically charged due to friction. The contact between two materials of opposite polarity creates an electrochemical interaction between the surface molecules, which is responsible for the generation of triboelectric charges on their surfaces. However, upon the separation, these triboelectric charges become the driving force for the electron to flow through the electrode to equalize the potential difference created (**Figure 2**) [20, 22].

1.2.4 Sports functional clothing

The growing popularity of textiles in the sports industry has increased the demand for functional clothing, which has become a critical aspect in improving a

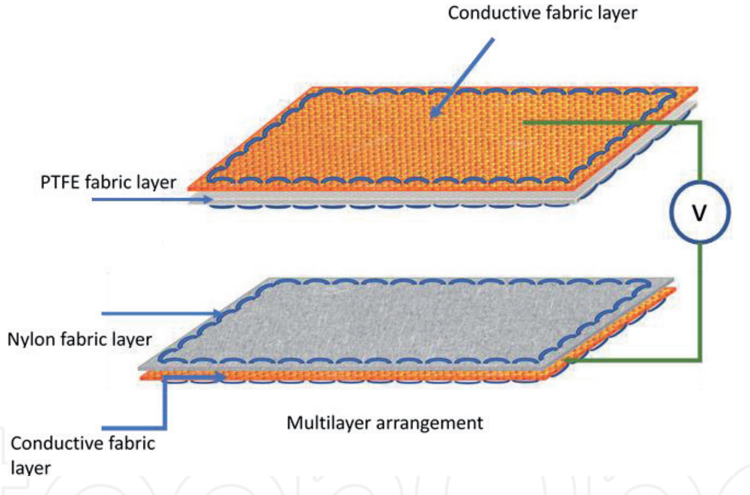

Figure 2.
Schematic of triboelectric nanogenerator arrangement [22].

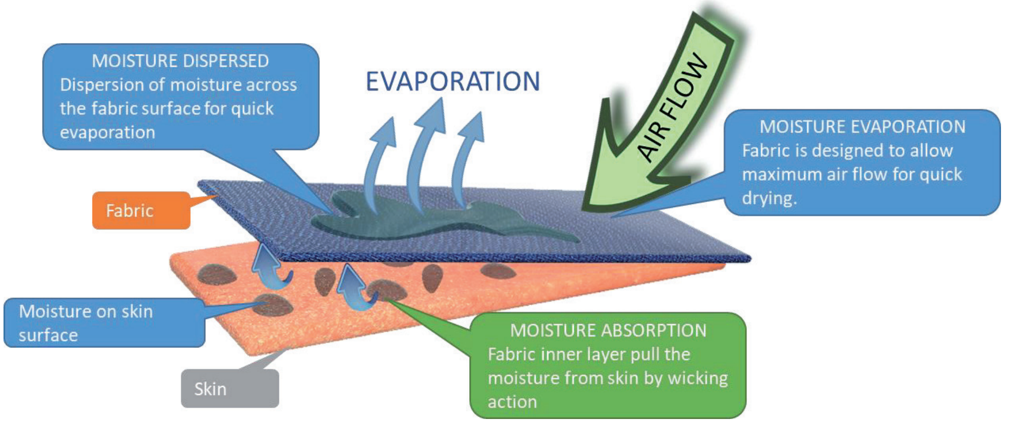

Figure 3.
Mechanism of moisture transport through sports clothing.

sportsperson's overall performance. The main characteristics of sports functional clothing are moisture management, quick moisture transport, temperature management, odor control, lightweight, and fit. The textile fiber is specially modified to enhance its surface area to facilitate moisture wicking helps in maintaining thermal balance during sports activity (**Figure 3**) [23]. Sports functional clothing is also used for enhancing the performance of the sportsperson by the mechanism of compression and aerodynamic design [23, 24]. The compression property of the garment helps in regulating the blood flow to a specific muscle groups providing enhanced energy and oxygen supply, which also helps in faster muscle recovery [14]. The aerodynamic design helps to reduce the wind and air resistance by systematically controlling the morphology of the fiber, shaping the garment, and structural arrangement of the fabric components [16].

2. Market and future scope

The need for functional fibers, processes, and technologies is growing in the 21st century, and such products are not being only used in apparel or garment, but also in other different applications, such as medical, automotive, agriculture, sports, geotextile, and others. The recent outbreak of COVID19 has resulted in more demand for medical textile products. The acceptance of smart healthcare products in daily life will be the next significant technological change going to happen globally. Smart Wearable E-Textile Medical Technology is one of the top-trending technology topics across the globe. It includes the integration of smart sensor/actuator materials in garments for non-invasive health monitoring. Such e-textiles help to detect the individual's vital signs and retransmit them *via* wireless sensor technology to provide continuous feedback on the health status. For the development of any functional or smart textile product, it combines knowledge from interdisciplinary backgrounds including material science, interfacial physics, biomechanics, textile engineering and design, and other engineering stream. Additionally, the need for new technologies is expected to be developed, which could bring down the manufacturing cost and make such products a commercially successful. It has been projected a massive growth rate of over 6% CAGR for the technical and functional textiles from 2020 to 2025, expected to reach over $222.4 billion global markets by 2025.

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